Modification of Rib Cross-sectional Properties of the Chinese Human Body Model according to the Chinese Skeletal Database

Xiaofan Wu , Jiapeng Li, Huida Zhang, Guibing Li, Linwei Zhang, Guojie Wang, Yu Liu

I. INTRODUCTION

The chest stiffness and mechanical properties of finite element (FE) human body models (HBMs) are correlated with the dimensions of the ribs and the thickness of the cortical bone [1]. The modeling of the HBM often relies on the dimensions of a specific volunteer. Even if the selected volunteer conforms to most of the anthropometry characteristics of the corresponding population (such as Chinese male at the 50th percentile), its representativeness for the average anatomical dimensions remains limited [2]. Therefore, the current work aims to enhance the representativeness of a Chinese 50th percentile male HBM in rib skeletal dimensions.

II. METHODS

A Chinese 50th percentile male HBM, called AC-HUMs 50M, was previously developed by CAERI (China Automotive Engineering Research Institute) based on the geometry data of a 50th percentile male volunteer. To further improve the representativeness of the key skeletal data of the AC-HUMs model, the skeletal data collected from hospitals located at seven major regions in China were aggregated into a skeletal dimension database, which includes overall cross-sectional dimensions, cortical bone thickness, etc. [3]. To build the database, a total of 245 samples were collected from these hospitals with 35 samples each hospital. These samples all came from Chinese adult males aged 18 to 80 years old (mean ± SD of 46 ± 17years). Altogether，38,955 individual data points were compiled, covering various skeletal components such as the skull, sternum, ribs, tibia, fibula, femur. The dataset includes measurements of both external dimensions and cortical bone thickness. Statistical analysis was performed on the database to calculate the weighted average rib cross-sectional dimensions. Then, the outer contour dimensions and the cortical bone thickness of the ribs on the original AC-HUMs model were modified to make them approach the statistical results.

III. INITIAL FINDINGS

Figure 1 compares the outer contour dimensions of the original and modified AC-HUMs ribcage. Overall, the outer contour dimensions of the ribs of original AC-HUMs are expanded, and the shape changes slightly. The rib cross-sectional dimensions of the modified model are closer to the statistical data (Table I), where Measurement Position 1 is at the end of the rib close to the sternum, which is divided into four equal parts, and Measurement Position 2 is the midpoint of the rib. Furthermore, the stiffness of the thoracic cage is increased under the impact conditions of cadaver tests [4-6], making it closer to the experimental channel range (Figs 2 and 3).

IV. DISCUSSION

The results imply that when HBMs are developed based on the geometry of a specific volunteer, this may affect their representativeness for the mechanical properties of the target population. However, the current study is limited at the general level (e.g. overall cross-sectional dimensions), and detailed properties, such as the variation of bone cross-sectional dimensions with positions, have not been considered. In subsequent versions, the modeling method of skeletal system in AC-HUMs will be optimised to make it closer to the statistical geometry of Chinese population, especially the cross-sectional dimensions and cortical bone thickness of the skull, ribs and long bones.

Y. Liu (e-mail: liuyu@caeri.com.cn; tel: +86 17843761276), X. F. Wu, J. P. Li, H. D. Zhang, L. W. Zhang and G. J. Wang are Researchers in China Automotive Engineer Research Institute Co., Ltd., Chongqing, China. G. B. Li is Professor of Electromechanical Engineering in the Department of Vehicle Engineering at Hunan University of Science and Technology, Changsha, China.

TABLE I
RESULTS BEFORE AND AFTER MODIFICATION OF SOME RIBS

	Measurement Position 1			Measurement Position 2		
	Mean/ mm	Difference before modification /mm	Difference after modification /mm	mean /mm	Difference before modification /mm	Difference after modification /mm
4th rib upper and lower diameter	11.92	0.61	-0.34	12.65	-0.84	-0.42
8th rib upper and lower diameter	13.32	-0.32	1.35	15.46	-1.05	-0.29
4th rib inner and outer diameter	9.05	-1.73	-0.41	8.16	0.037	0.51
8th rib inner and outer diameter	9.39	-1.23	0.38	8.02	-0.062	0.87

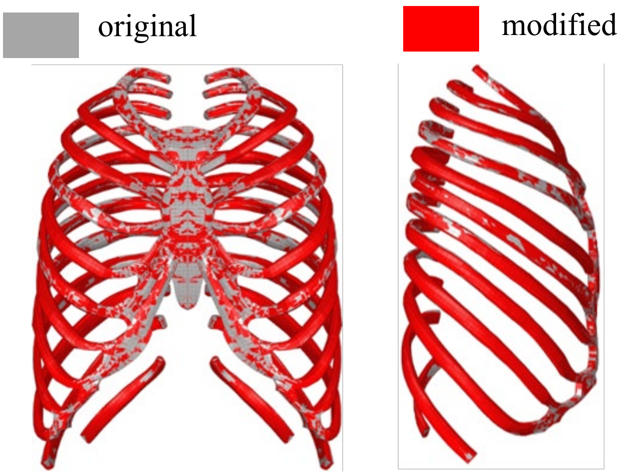

Fig. 1. Comparison of sternum and rib shapes before and after modification.

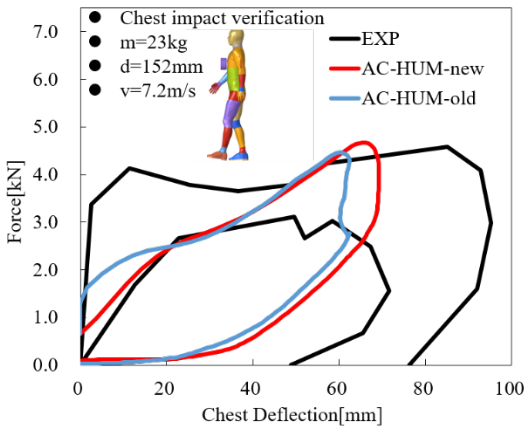

Fig. 2. Simulation results of chest frontal impact.

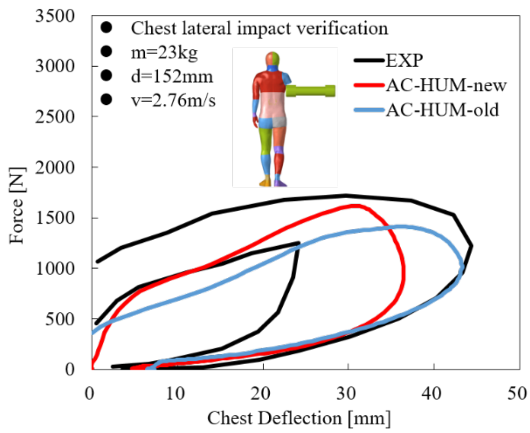

Fig. 3. Simulation results of chest side impact.

V. REFERENCES

[1] Xiao, S., *et al.*, *Acta Mechanica Sinica*, 2017.
[2] Holcombe, S. A., *et al.*, *J Anatomy*, 2019.
[3] Fan, T., *et al.*, *J Mech Med Biol*, 2024.
[4] Kroell, C., *et al.*, SAE Technical Paper, 1971.
[5] Kroell, C. K., *et al.*, *Stapp Car Crash J*, 1974.
[6] Shaw, J. M., *et al.*, *Stapp Car Crash J*, 2006.